Determination of the Best Area for Collection of Flashflood Water using Geographic Information Systems and Digital Elevation Model

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Abstract - **Modern techniques of remote sensing (RS) provide tremendous potentiality for monitoring dynamic changes in large surface water bodies, extracting hydrological parameters, and modeling water balance. Normalized Difference Water Index (NDWI) using Near Infrared (NIR) and green channels of Lands at can delineate and enhance open water features. Geographical techniques such as Geographical Information Systems (GIS) and remote sensing help in locating suitable water recharging and / or harvesting sites in recent last years. This water can be useful for constructing a dam or basin in the study area. In addition, they can be an effective way of providing water for agriculture and pasture areas, which are furthest from the Nile. The objective of this paper is to determine hydrological network and select the best area of flash flood water accumulation. This study had been carried out in the locality of Omdurman (Sudan). It had indicated the usefulness of the combination of RS and GIS techniques in the determination the best possible site for floodwater accumulation.**

Keywords: Rain water, Normalized Difference Water Index, Digital Elevation Models, Water balance, Omdurman geological formation.

I. INTRODUCTION

Flash flood is a rapid onset of flood with a short duration and a relatively high peak discharge. It occurs rapidly, generally within one hour of rainfall, and sometimes accompanied by landslides, mudflows, bridge collapse, damage to buildings, and facilities[3].

Flash flood in cities leads to high levels of water in the streets and roads, causing many problems such as bridge collapse, building damage and traffic problems. It is impossible to avoid risks of floods or prevent their occurrence; however, it is plausible to work on the reduction of their effects and to reduce the losses, which they may cause.

Geographic Information System (GIS) is a powerful tool for Flash flood mapping. Mapping flash flood will be beneficial to urban and infrastructure planners, risk managers and disaster response or emergency services during extreme and intense rainfall events[4] .studied the generation of flash flood map for Najrancity Saudi Arabia using Satellite images and GIS tools. He used SPOT and SRTM DEMs data for which accuracy assessment was achieved by using checkpoints, obtained by GPS observations. Analytical Hierarchical Process (AHP) was used to determine relative impact weight of flood causative factors to get a composite flood hazard index (FHI). The causative factors in this study were runoff, soil type, surface slope, surface roughness, drainage density, distance to main channel and land use. All causative factors were prepared as layers in ArcMap and integrated to produce a final flood hazard map. The areas in high-risk flood zones were obtained by overlaying the flood hazard index map with the zone boundaries layer. The affected land area and population number were determined and compared.

The digital elevation model has an impact on the quality of the result. Vertical accuracy for two data sources of DEMs were checked and compared with 51 ground control points (GCP) distributed within the study area. The Geoid undulation had been calculated using elevations of available benchmarks in the study area. The orthometric heights of GCP points were transformed. Vertical accuracy had been determined by comparing the computed Z-coordinate values of checkpoints, with those obtained from GPS post processing surveys. The root mean square error of elevation differences (RMSE z) for SPOT was ±5.64 m, while for SRTM was ±7.59 m[4]

In addition, there were many studies for analyzing flood hazard. One of these study was done in area of Awash River Basin by Getahun and Gebre in 2015.Flood generating factors, (slope, elevation, rainfall, drainage density, land use, and soil type) were rated and combined to delineate flood hazard zones using a multi-criteria evaluation technique in a GIS

environment. The weight of each flood generating factor was computed by pair wise comparison for a final weighted overlay analysis to generate the flood hazard map. The flood hazard map indicates that 2103.34, 35406.63, 59271.09, 162827.96, and 1491.66 km which correspond to 1.8%, 30.9%, 51.7%, 14.2%, and 1.3% respectively indicating very high, high, moderate, low, and very low flood hazard, respectively. The flooded areas along the Awash River were mapped based on the 5% exceeding highest flows for different return periods using the HEC-RAS model. GIS for spatial data processing and HEC-GeoRAS were used for interfacing between HEC-RAS and GIS. The areas along the Awash River simulated to be inundated for 5, 10, 25, 50 and 100 years return periods. The flooded areas were high particularly from Dubti down to Lake Abe for all return periods. The hazard map indicates that the high and very high flood hazard threats are in the downstream part of the basin in the South West direction. which is low-lying flat areas of the Awash River basin. The moderate flood hazard covers the largest area, which is 52%.There is a low and very low flood hazard probability in the west highlands that is the upper part of river basin, in the northwest and southwest peripheries.[2]

**a) Remote Sensing (RS) and Geographical Information Systems (GIS)**

Remote sensing is a technique, which made it possible to obtain and distribute information rapidly over large areas by means of sensors operating in several spectral bands, mounted on aircrafts or satellites. The spectral bands used by these sensors cover the whole range between visible and microwaves. Rapid developments in computer technology and the Geographical Information Systems (GIS) help to process Remote Sensing (RS) observations from satellites in a spatial format of maps. The spatial visualization of information derived from RS techniques with other datasets provides tremendous potential for identification, monitoring and assessment of floods[5].

II. METHODOLOGY

a) The Study Area

The study area is the locality of Omdurman, bounded by latitude 16° 39' 52.6"N (Upper), 15° 54' 45.1" N (Lower) and longitude 31° 49' 46.4"N(Upper), 32° 36' 31.9"N (Lower), on the western bank of the River Nile and its tributary; the White Nile comprising a total of 8203.936km^{2}approximately. It is linked with the two main cities, Khartoum and Khartoum North, by the White Nile and El Ingaz bridges and Shambat and Halfayat El Mulook bridges respectively (see Figure 2).Omdurman features a hot desert climate, with only the months of July and August seeing significant precipitation

averaging little over 155 millimeters per year. Expansive soil is mainly composed of sedimentary rocks such as shell, clay stone, lime stone, and rich in magnesium. The geological units in the study area are composed of superficial deposits, volcanic rocks, cretaceous sedimentary rocks and basement complex. The surface of the locality is characterized by gently rolling terrain and the end of the water discharge is generally the Nile River.[8] [9]
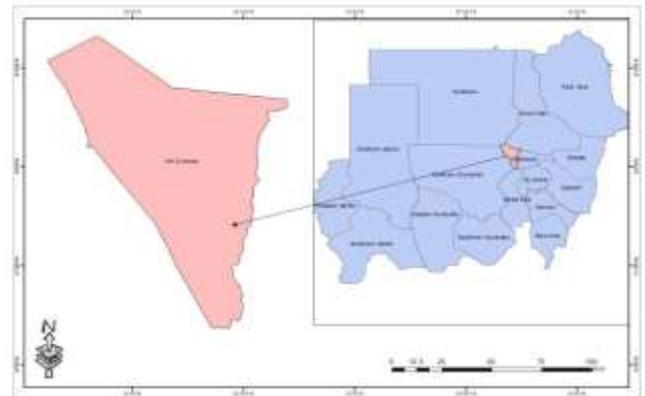
Figure 1: Study Area (Omdurman Locality)

The Agricultural (cultivated and non- cultivated) area totaled one million dedans. The registered part of this area is almost 954000 Fedans. Land cover refers to the physical surface of the earth, including various combinations of vegetation types, soils, exposed rocks and water bodies as well as anthropogenic element (see Figure 2).
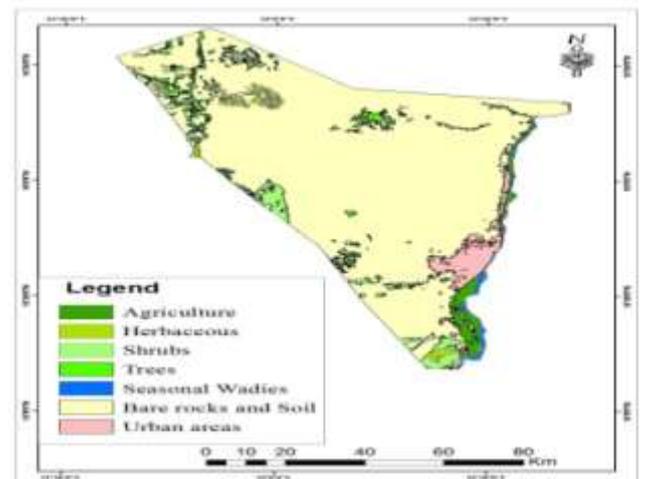
Figure 2: Land Cover of Omdurman Locality

Source of satellite imagery in figure4 is the Department of Agriculture and Water Resources (2017) land use management.

b) Digital Elevation Model (DEM)

Digital elevation models derived from remote sensing data are usually applied. Moreover, these digital elevation models have intrinsic errors that introduce bigger uncertainties in results than the associated hydrological projections. On the other hand, estimation of flooded areas through remote sensing images provide accurate information, which could be used for the construction a relationship between river level-flooded area and vulnerability assessment[7].

A Digital Elevation Model (DEM) of the study area was extracted from the Shuttle Radar Topography Mission (SRTM) data available at 30 meters resolution using arc hydro tools. The Paz and Collischonn approach were applied to eliminate sinks form the SRTM data and to obtain the local direction network[6]. DEM was employed to offer varieties of data that assist in producing landforms maps, soil types and hydrology information. Drainage networks and sub-catchment boundary of the studied areas were extracted from DEM in order to investigate the spatial relationship of agriculture fields and the catchment-drainage networks[1].
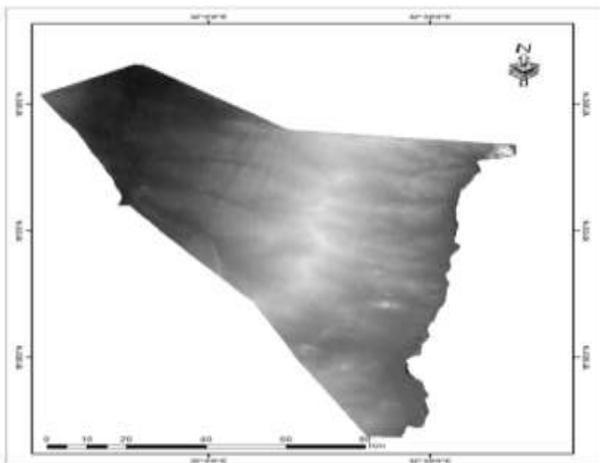

Figure 3: DEM of Study Area

c) Data Sources

DEM had downloaded from www.earthexplorer.USGS.gov of 30 meters resolution captured by ASTR sensor in 2016.

d) Data processing

The software used for data processing is the Arc Map version10.3 in the following steps:

1. Fill

Spatial Analysis Tools/Hydrology/fill had been chosen from the tools bar to treat extreme rises or falls. This step is to fill extreme unexpected height values in digital height layer data by eliminating them and a new layer with no rises or falls is constructed. In this way, a layer is added to the list of contents of the project which is the same as the previous file.

2. Flow Direction

Spatial Analysis Tools/Hydrology/Flow Direction from the tools bar had been Chosen for the purpose of determining the direction of the water flow from one cell to adjacent cells.

3. Flow Accumulation

Spatial Tools/Hydrology/Flow accumulation from the tools bar had been Chosen to determine shapes of the main drainages within the basin by collecting flow for a given cell by calculating the number of cells where the water accumulates where it gives the main drainages a valve of 1 and a zero) to the other areas where the main drainages appear with no color (White) and the remaining areas appear with a black color.

4. Con, Stream link and Order

Spatial Tools/ Conditional /Con from the tools bar is Choose to determine drainages other then the main ones in areas determined and entered prior(given number of cells).

All previous steps at cell level or tributary and the tributaries should link inside a single wadi /river. Therefore, Spatial Tools/Hydrology/Stream link tool bar was chosen for the purpose of determination of all junctions between tributaries and points where grid parameters meet. Every junction had been given a unique number.

The Spatial Tools/Hydrology/Stream Order had been chosen from the tools bar to interpret river ranks in the area of the basin and their number. It should be noted that the number of river ranks points to the strength of the river. See Figure (4).
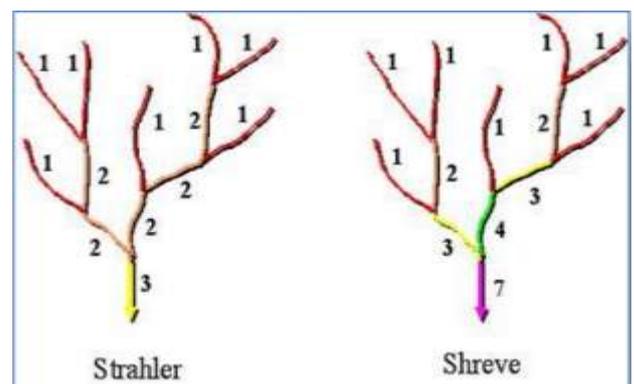

Figure 4: Stream Order

5. Stream to Feature

The water grid had been transformed from raster to vector by the Order Spatial Tools/Hydrology/Stream to Feature tools bar to have a line layer from which the number and length of the ranks of the basin are determined. The result is shown in Figure (5).
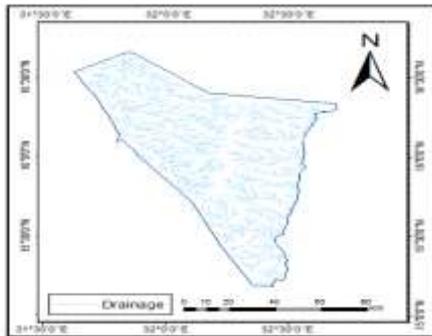

Figure 5: Stream to Feature (Drainage)

A shape file of point type is constructed and the editor bar is effected for the same file in order to determine accumulation points for the main drainages in the study area.

6. Snap Pour Point, Watershed and Raster to Polygon

Choose Spatial Tools/Hydrology/ Snap Pour Point from the tools bar to put all points determined in the linear file on the main drainages layer (The grids file).

This step determines the contributing areas(basins) in water accumulation around the course (drain) through the use of Spatial Tools/Hydrology/ Watershed tools bar. The result of these last two steps had been combined with the coming (6.6) step is shown in Figure (6).

From the tools bar, Conversion Tools/From Raster/ Raster to polygon is used to transform resulted basins in the previous step from raster file to vector file in order to be able to calculate basins areas.
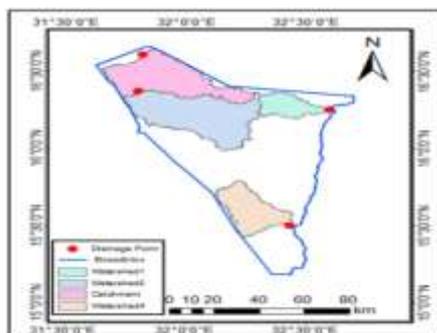

Figure 6: Snap Pour Point and Watershed

III. RESULTS AND ANALYSIS

1. Determination of secondary tributaries within the study area had been reached at after many experimental trials by entering the number of cells appropriate for tributaries to appear (1000 and 5000 cells). Many trials are to be performed because any entered value displays a certain number of secondary tributaries which are known from Google Earth, (Show in Figure4).

2. Determination of Basin Main Tributaries Points: A map showing basin points of the main tributaries chosen based on the river higher rank associated with a tributary (four ranks). These points had been chosen according to the topography and falling on the main tributaries in areas considered to be end discharge for these tributaries as in Figure (7).

3. Finding points of charging basin and determination of the best point for water accumulation.

4. A map showing charging basins for end discharge points of the main tributaries had been achieved from the watershed process, from the tools bar, for the points determined in the previous step. (Shown in Figure7)

5. A map showing the best point for water accumulation from points determined in the previous step because it resulted in producing the largest charging basin area wise and it is the furthest point from the Nile. This is an indication that the point falls on a place where water is rare during summer and winter seasons. That place is also a residential area. This leads to the desired benefit from this study where it points to the best possible point for constructing a dam or reservoir to store waters that can be benefited form. (Shown in Figure 8)
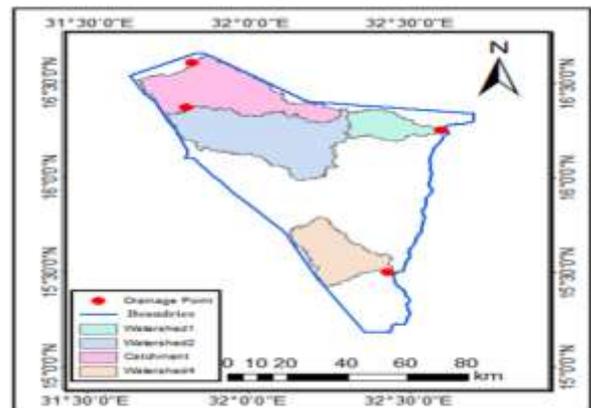

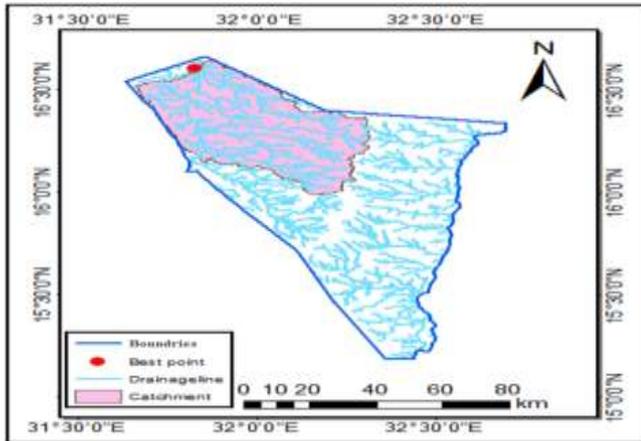**Figure 7: Determination of the Best Point for Water Accumulation**

Figure 8: Best Area for Pool Water

IV.CONCLUSIONS

In general, this study had concluded that it is possible to determine the best point location for water accumulation using appropriate steps of Hydrological Analysis contained in Geographical Information Systems; namely Arc GIS version 10.3 with the help of a Digital Elevation Model (DEM) to benefit increase of water during autumn. That point can be benefited from by constructing a dam or a basin for the purpose of collecting water to be used in all areas of life in conjunction with agriculture and pasture for areas that are for away from the Nile in the study area.

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